INTERSTATE COMMERCE COMMISSION.

REPORT OF THE CHIEF INSPECTOR OF SAFETY APPLIANCES COVERING HIS INVESTIGATION OF AN ACCIDENT WHICH OCCURRED ON THE SOUTHERN RAILWAY NEAR OYAMA, N. C., ON MARCH 31, 1913, ACCOMPANIED BY REPORT OF THE ENGINEER-PHYSICIST OF THE BUREAU OF STANDARDS COVERING HIS INVESTIGATION OF THE BROKEN RAIL CAUSING THIS ACCIDENT.

January 7, 1914.

To the Commission:

On March 31, 1913, there was a derailment of a freight train on the Southern Railway near Oyama, N. C., which resulted in the death of three employees and the injury of a trespasser. After investigation as to the nature and cause of this accident, and the circumstances connected therewith, I beg to submit the following report:

The Asheville division of the Southern Railway, on which this accident occurred, is a single-track line operated under the manual block system. At the point of derailment the track runs east and west; it is laid with 33-foot, 80-pound steel rails, single spiked to oak ties, 18 or 19 to the rail, with 8 inches of rock ballast, the track being maintained in good condition.

Westbound freight train No. 73, running from Salisbury, N. C., to Asheville, N. C., a distance of 141 miles, consisted of engine No. 646, 17 loaded and 17 empty cars and a caboose, and was in charge of Conductor Boyle and Engineman Eagle. This train left Salisbury at 2.21 a. m., 21 minutes late, and left Newton, the last telegraph station east of the point of derailment, at 4.43 a. m., 28 minutes late. The derailment occurred 2.2 miles east of Oyama, N. C., near milepost S–51.8, at about 4.50 a. m. The engine, tender, and 16 cars were derailed on the south side of the track, 11 cars were destroyed, and the track was torn up for a distance of 330 feet. The conductor, engineer, and fireman were killed.

The speed of the train at the time of the derailment was 25 or 30 miles per hour. There was a speed restriction of 30 miles per hour for freight trains in effect on this division. At the time of the accident the weather was foggy.

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Approaching the scene of the accident from the east there is a 2° curve to the south 2,300 feet long, followed by a tangent 2,700 feet in length. Following this tangent is a 1° curve to the north 5,400 feet in length. About 1,800 feet of this tangent is on a grade of 0.95 per cent descending from the east, this grade being immediately followed by an ascending grade of 0.9 per cent about 1,400 feet in length. The derailment occurred about 1,122 feet from the east end of the tangent, 300 feet from the foot of the descending grade, on a fill 5 feet high on the south and 2½ feet high on the north. It was caused by a broken rail on the south side of the track. The rail was broken in eight places, the shortest piece being about 7 inches long and the longest piece 16 feet 2½ inches long.

Engine No. 646 weighed 197,750 pounds, with 176,650 pounds on the driving wheels. This engine was built in 1904; it was rebuilt in 1912, and at the time of the accident was in good condition. The last preceding train over this track was eastbound freight train third No. 72, which passed the scene of derailment at approximately 3.05 a. m. This train was hauled by engine No. 823, of the same class as engine No. 646, and consisted of 20 loaded cars. The engineman of this train stated that at the point where this derailment occurred his train was running at the rate of 20 or 25 miles per hour, and he did not notice anything unusual when his train passed that point.

The section on which the derailment occurred included 6½ miles of main track. The section foreman stated that ordinarily he had four men in his gang, but at the time of the accident he had but three. He stated that this section of the track was carefully gone over by his men three times each week, and that he made an examination of the track at least twice a week for the express purpose of looking for broken rails; he had not found a broken rail on this division for at least three months.

As this accident was caused by a broken rail arrangements were made with the Bureau of Standards, Department of Commerce, for the purpose of having this rail examined and the cause of its failure ascertained. This examination was conducted by Mr. James E. Howard, engineer-physicist, of the Bureau of Standards, and the report regarding his examination, with the accompanying illustrations, is attached to and made a part of this report.

The broken rail which caused this accident was manufactured by the Tennessee Coal & Iron Co.; it was 33 feet long, weighed 80 pounds to the yard; was rolled in November, 1904, and laid in the track in January, 1905. The first break in this rail was found 16 feet 2½ inches from the east end, while that part of the rail west of this fracture was broken in 9 pieces, ranging from 6⅝ inches to 5 feet 5 inches in length, the last break being near the splice plate at the west end. From the appearance of the fractures and the battered

ends of the pieces of rail it is believed that the first break occurred either between pieces Nos. 2 and 3, or between pieces Nos. 3 and 4, shown in illustration No. 1. A transverse fissure 1 inch in diameter was found at the fracture between pieces Nos. 3 and 4, and that fact, together with other evidence brought out by Mr. Howard's examination, indicates that this fracture was the first one to be formed. The fractures to the east of this initial fracture differ from those to the west in that the fragments were bruised on different ends, from which it is inferred that the several fractures were caused by two trains which moved in opposite directions. It also appears that the receiving ends of fragments Nos. 1 and 2 were bruised and displaced in such a manner as to indicate that this had been done by an east-bound train. The manner in which the rail broke is clearly shown in illustrations Nos. 1, 2, and 3. Illustration No. 4 shows the transverse fissure 1 inch in diameter on the fractured surface of fragment No. 4. It will be noted that this transverse fissure was located on the gauge side of the head nearly over the web. This fissure is similar to the fissures found in the broken rails which caused the accidents on the Lehigh Valley Railroad at Manchester, N. Y., August 25, 1911, and on the Louisville & Nashville Railroad near Hay's Mill, Ala., October 1, 1912, upon which reports have been made.

The 17 other rails which had to be replaced were bent and twisted out of shape but were not fractured.

In view of the fact that the formation of transverse fissures in rails is a grave menace to the safety of railroad travel, the facts disclosed by this investigation and the conclusions reached by Mr. Howard as a result of his study and tests of this rail are of particular interest and value.

Mr. Howard points out that transverse fissures are progressive in their character and development. They have been observed at different stages in their growth from 0.30 inches in diameter to a maximum of 2½ inches. The material and locality in which they exist have been defined. They have been found only in steel rails, where they commonly are developed on the gauge side of the head, or over the web. In their development from a minimum to a maximum diameter the extension takes place while the rails are under service condition in the track.

Furthermore, Mr. Howard calls attention to the fact that—

> The rate of development, however, of a transverse fissure should in general be an accelerating one, since the resistance of the rail diminishes as the fissure extends.
>
> It is a question of interest whether an effect caused by an excessive load, but not immediately resulting in actual rupture, is further accentuated by the application of lesser loads; that is, whether the effect of an overload coming from the drivers of the engine would be further increased by the lesser wheel loads of the train. Laboratory tests on the effects of repeated stresses have

shown, however, that many million repetitions of a lesser load may be applied to a steel bar without causing rupture, while substantially the normal number of repetitions of a maximum load will thereafter effect a fracture.

This is so vital a feature in the use of railway material that confirmatory data are desirable to acquire from independent sources. Provided these indications are trustworthy, it follows that the limit of endurance of a steel rail is not necessarily measured by total tonnage, but rather by the number of repetitions of high wheel loads to which it is exposed.

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Frequent rail failures are regarded as sufficient warning that railway practice is approaching the limit of endurance of rail steel.

The facts disclosed by the investigation of this derailment emphasize the statements made in the report regarding the derailment on the Louisville & Nashville Railroad, near Hay's Mill, Ala., where it was stated that the combined bending stresses and intense wheel contact stresses which attend the service conditions of steel rails appear to be the cause of the formation of these fissures. The insidious character of these fissures and their menace to safe travel by rail justify the conclusion reached that there is an absolute necessity of making a complete investigation of track and wheel conditions for the purpose of determining the effect thereon of the recent types of locomotives and cars with their greatly increased wheel loads.

Respectfully submitted.

H. W. Belnap.
Chief Inspector of Safety Appliances.

REPORT OF THE ENGINEER-PHYSICIST.

I have the honor to report upon the fracture of a steel rail which occurred on the Asheville division of the Southern Railway Co., near Oyama, N. C.

Freight train No. 73, westbound, was wrecked on March 31 last at about 4.50 o'clock a. m., due apparently to the fracture of this rail, resulting in the death of three persons—the engineer, fireman, and conductor of the train, all of whom were riding on the engine, which overturned.

The derailment occurred on a tangent near the foot of a 0.95 per cent descending grade. The train consisted of engine No. 646, weighing 197,750 pounds; tender 120,000 pounds; and 34 cars and caboose. The speed of the train was estimated at 25 miles per hour.

The fractured rail was an 80-pound section, 33 feet long, 5 inches high, 5 inches width of base, and $\frac{9}{16}$ inch thickness of web. It was rolled by the Tennessee Coal and Iron Co., and branded as follows: "T C I Co A S IIIIIIIIII 04." It was laid in the track January, 1905, single spiked on oak ties, 18 or 19 to the rail, and rested upon 8 inches of rock ballast. It was fractured across its full section in eight places, the shortest piece being about 7 inches long, the longest, 16 feet $2\frac{1}{2}$ inches.

The derailed train left the track to the left, through the opening made by the fractured rail, the engine and 16 cars overturning as they went down a 5-foot embankment.

About two hours prior to this occurrence, or soon after 3 o'clock a. m., an eastbound freight train passed over the same track, this being a single-track road. This earlier train, of 20 cars, 3d No. 72, was hauled by engine No. 823, of the same class as the engine of the wrecked train. It passed the scene of the derailment at an estimated speed of 20 to 25 miles. The evidence furnished by the fractured rail indicates that its initial rupture was caused by this eastbound train, yet none of its crew felt anything unusual when passing over this point. The engineer stated that he had, in his experience, run over broken rails, and the effect was about the same as when passing over a broken angle bar.

In the repairs of the track which followed the derailment 18 new rails were used, 10 on the left side, 8 on the right. There was only 1 broken rail, the other 17 were twisted and bent.

Photographic prints, reproduced in figures Nos. 1, 2, and 3, show the appearance of the fractured rail, viewed from the gauge side. A transverse fissure 1 inch in diameter was present in the head, on the gauge side, on the fractured surface between fragments Nos. 3 and 4. Figure No. 4 shows the appearance of this transverse fissure.

The first fracture of the rail, approaching from the east, was 16 feet 2½ inches from that end, the last fracture was abreast the splice plates at the west end. All lines of rupture extending through the full cross section appeared to have had their origins at the head of the rail, thence extending downward through the web and the base.

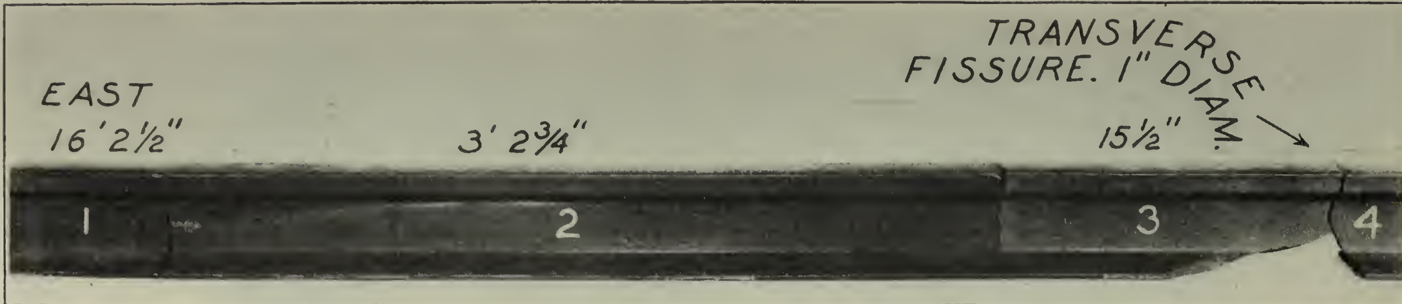
The fracture which was first formed is believed to have been either that between fragments Nos. 2 and 3 or that between Nos. 3 and 4. The presence of a transverse fissure, 1 inch in diameter, between Nos. 3 and 4 would suggest that line of rupture as the incipient one, and evidence found on the running surface is not inconsistent therewith. The battered condition of the abutting surfaces of Nos. 2 and 3 so far obscure their primitive appearance that it is not feasible to judge of those surfaces in respect to priority of occurrence.

Sufficient evidence is presented in the rail to indicate that all other fractures were of subsequent formation. But those on the east of the probable incipient line of rupture differ from those on the west. The east and west fragments were bruised on different ends, from which it is inferred that the several fractures were caused by two trains which moved in opposite directions.

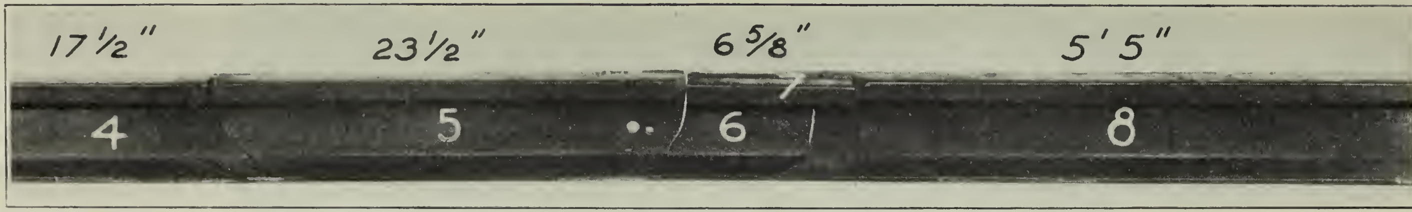
The receiving ends of fragments Nos. 1 and 2 were bruised and depressed with reference to the direction in which train 3d No. 72 passed over the track, which establishes their priority over those believed to have been caused by the wrecked train No. 73. The bruises on the other fragments faced the direction in which the wrecked train moved, and were clearly secondary with respect to those first mentioned. From the testimony it appears that the track had been made practically new within a period of 17 months, and was in first-class condition, so far as known. Under such conditions there would be a reasonable opportunity for a slow-moving freight train successfully to pass over a well-spiked track in which there was a rail which had been broken by the engine hauling that train.

The wheels which are responsible for the fracture of a rail may not themselves be derailed, and light wheel loads might subsequently pass over such track in safety. The engine next following would, however, encounter adverse conditions, such as might lead to derailment, and this is believed to be descriptive of what occurred in the present case.

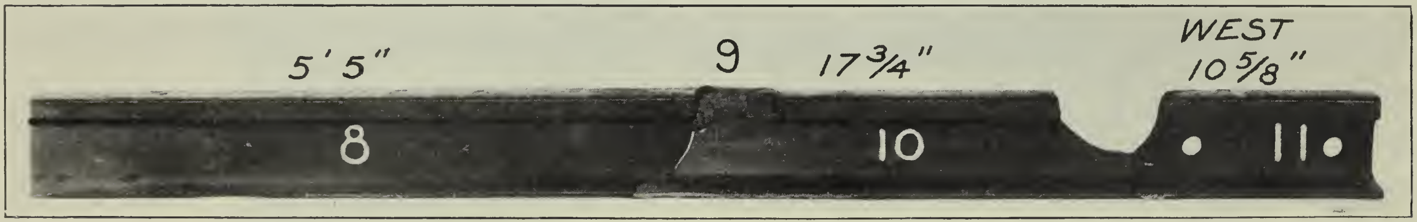
From the markings on the fragments located west of No. 3 it is evident they were caused by the wrecked train. The train drifted



No. 1. Easterly portion of fractured rail, gauge side; fractures 1—2 and 2—3 attributed to eastbound train 3d No. 72.



No. 2. Middle portion of fractured rail, gauge side; fractures attributed to wrecked, or westbound, train No. 73.



No. 3. Westerly portion of fractured rail, gauge side; fractures attributed to wrecked, or westbound, train No. 73.

No. 4. Transverse fissure, diameter 1 inch, on fractured surface of fragment No. 4.

to the left and made its exit from the track, or began to do so, in the opening covered by fragments Nos. 4 to 10, inclusive. The receiving end of fragment No. 5 was much bruised and a longitudinal crack started in the head, caused by blows in part directed in an outward, oblique direction. The head of fragment No. 6, next following, was split longitudinally a length of 8 inches. The head of the rail, at the middle of its width, was struck apparently by the flange of a wheel, which acted as a wedge to split this short fragment. Figure No. 5 shows the appearance of the split head, detaching pieces Nos. 6 and 7, and also shows the battered end of No. 8.

Further effects of this kind were exhibited by fragments Nos. 9, 10, and 11, shown by figure No. 6. Glancing blows were received by the rail head corresponding in direction to that taken by the wrecked train in leaving the track. In these views, looking down upon the head of the rail, the gauge side is the lower side in the figures.

Chemical analyses of the metal gave the following results:

Mark.	Carbon.	Manganese.	Silicon.	Sulphur.	Phosphorus.
A	0.71	0.78	0.006	0.025	0.094
B	.68	.79	.004	.023	.089
C	.70	.79	.005	.027	.103

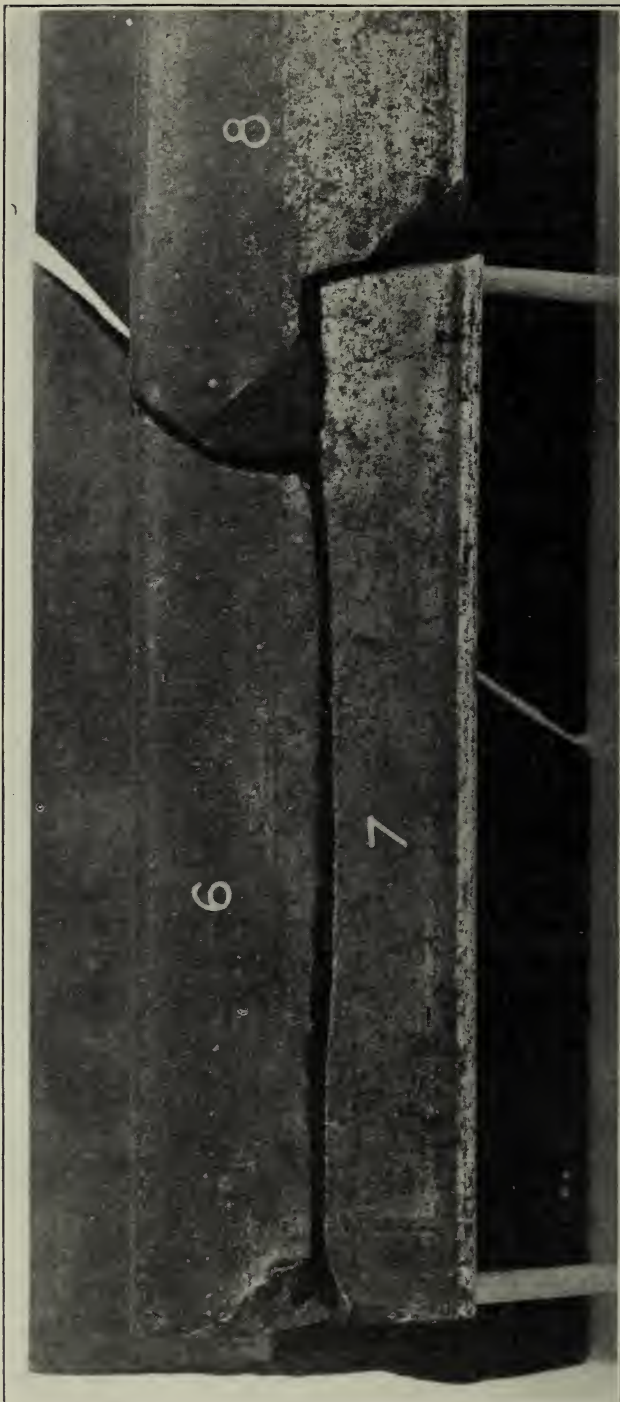
Samples A, B, and C represent the metal near the running surface of the head, at the center of the head, and in the upper part of the web, respectively. Chips for analysis were taken from fragment No. 3.

Tensile tests of the steel were made with specimens taken from the head of the rail. One specimen was taken from fragment No. 3 and two from fragment No. 2. One of the latter, marked 2b, was annealed before testing. The results of the tests were as follows:

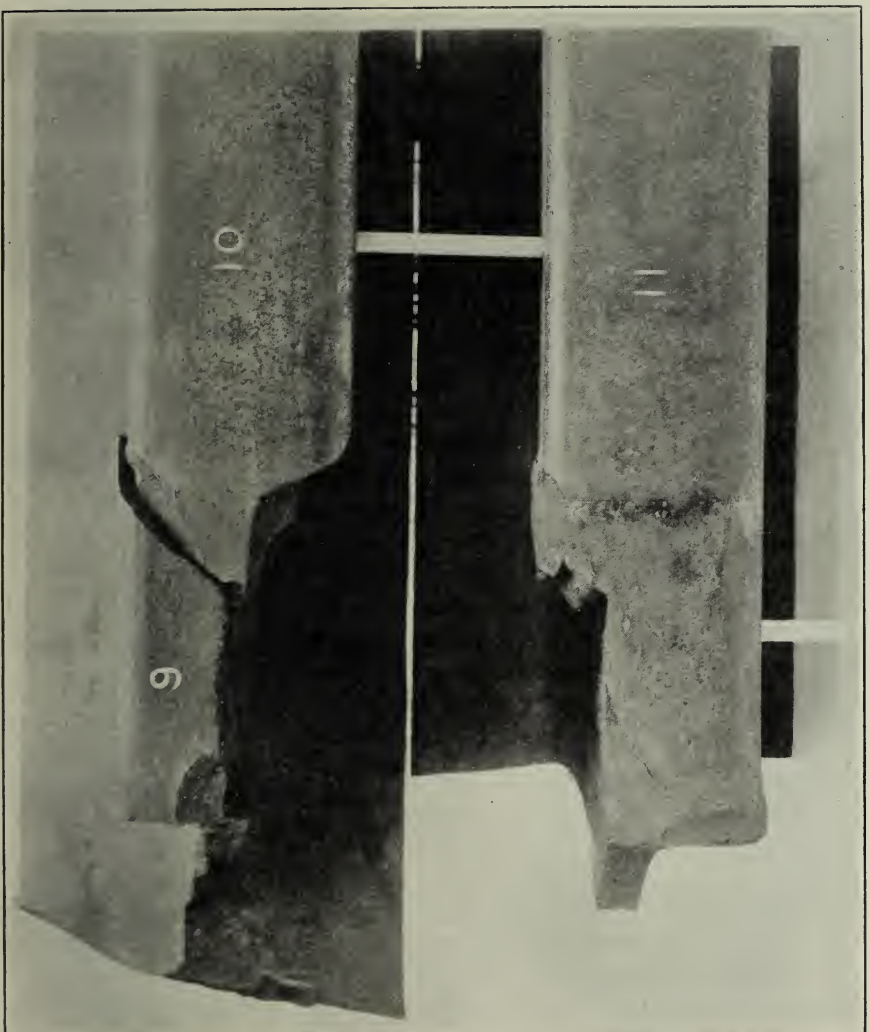
Tensile tests, head of rail, stems about 1.129 inches diameter by 10 inches long.

Marks.	Elastic limit per square inch.	Tensile strength per square inch.	Elongation in 10 inches.	Contraction of area.	Appearance of fracture.
	Pounds.	*Pounds.*	*Per cent.*	*Per cent.*	
1	[1] 51,000	65,000	0.25	0.1	Granular.
2a	[2]	63,200	[3]	[3]	Do.
2b	54,700	66,700	0.9	0.7	Granular; contained an incipient transverse fissure 0.30 inch in diameter.

[1] About. [2] Not well defined. [3] Inappreciable.



No. 5. Split head, separating fragments Nos. 6 and 7, and battered end of No. 8.



No. 6. Detached fragment No. 9, and ends of Nos. 10 and 11, battered by oblique end blows.

The high phosphorous content and the brittleness displayed by the steel in the tensile tests will each be noted.

An incipient transverse fissure was disclosed in the fractured surface of the annealed specimen, the appearance of which is indistinctly shown by the upper two fractures illustrated in figure No. 7. The fissure had a diameter of 0.30 inch, a part of which possessed a bright silvery luster. This part was crescent shaped. The balance of the fissure was dull in luster and similar in appearance to the incipient place of rupture of a tensile specimen of this grade of steel. The lower two fractures illustrated in figure No. 7 represent the surfaces of the unannealed specimen.

Transverse fissures commonly present smooth silvery surfaces, except at their nuclei, which are irregular. The smoothness of the opposing faces is attributed to the battering effect which they have upon each other when the rail is exposed to the usual bending stresses of service. The silvery luster is lost when the fissure has extended in size, reached the periphery of the rail section, and air admitted to the surfaces. The similarity in appearance of the nucleus of a transverse fissure and that of a tensile specimen is consistent with the explanation which has been offered to account for the development of transverse fissures in the heads of rails. Each are taken to be due to overstraining loads of tension. In the rail internal strains of compression immediately below the running surface, induced by the wheel pressures, tend to cause transverse fissures by strains of tension at places in the cross section next below, where the bending loads alone would not cause the maximum longitudinal tensile stresses to which the steel is believed to be exposed.

The formation of transverse fissures in rails is a matter of such gravity, menacing the safety of travel, that the acquisition of any data relevant thereto is of interest and value, and further discussion of the subject will be desirable until means of improvement are fully understood and adopted and present danger eliminated so far as may be.

Transverse fissures are progressive in their character and development. They have been observed at different stages in their growth from 0.30 inch diameter to a maximum of 2½ inches. The material and locality in which they exist have been defined. They have been found only in steel rails, where they commonly are developed on the gauge side of the head, or over the web. In their development from a minimum to a maximum diameter the extension takes place while the rails are under service conditions in the track. It is almost axiomatic that conditions which cause the extension of a transverse fissure would primarily be adequate to cause the incipient formation of one. Stresses which are received subsequent to the initial formation of a transverse fissure are doubtless also present in the track prior to such development.

No. 7. Fractured ends of tensile specimens 2a and 2b. A transverse fissure, diameter $\frac{3}{16}$ inch, was disclosed in specimen 2b.

Progressive fractures are the result of repeated stresses. If the loads were of constant magnitude the interval of time between the incipient stage and complete rupture of the material would be a brief one. In railway service the loads are variable, and maximum bending stresses at any given place in the track are doubtless of infrequent occurrence, hence it follows that the development of transverse fissures will not always progress at a rapid pace, and we are enabled to detect fissures in different stages of their development. The cold rolling of the head by the wheels necessarily affects the entire length of the rail, hence that component of the rupturing stress is certain to be present in all parts of its length.

The rate of development, however, of a transverse fissure should in general be an accelerating one, since the resistance of the rail diminishes as the fissure extends.

It is a question of interest whether an effect caused by an excessive load, but not immediately resulting in actual rupture, is further accentuated by the application of lesser loads; that is, whether the effect of an overload coming from the drivers of the engine would be further increased by the lesser wheel loads of the train. Laboratory tests on the effects of repeated stresses have shown, however, that many million repetitions of a lesser load may be applied to a steel bar without causing rupture, while substantially the normal number of repetitions of a maximum load will thereafter effect a fracture.

This is so vital a feature in the use of railway material that confirmatory data are desirable to acquire from independent sources. Provided these indications are trustworthy, it follows that the limit of endurance of a steel rail is not necessarily measured by total tonnage, but rather by the number of repetitions of high-wheel loads to which it is exposed.

A practical difficulty lies in judging what constitutes an overload and establishing the line of demarcation between safe and unsafe loads for cases of repeated stresses. But an increase in wheel loads is obviously attended by a closer approach to the limit of endurance of the rail regardless of the grade of steel used.

Frequent rail failures are regarded as sufficient warning that railway practice is approaching the limit of endurance of rail steel. Material on which we daily trust our lives should not be strained so close to the danger line as to make the question of the limit of safe loading a debatable one.

It is difficult to see how ultimate success in the safe use of railway material can be attained in the absence of information upon the actual stresses involved. Recourse must be had to track experiments to ascertain what fiber stresses the rails are exposed to.

Experiments conducted by the undersigned 18 years ago furnish certain data on this subject, pertaining to conditions as they then existed.

From these early tests the following results are taken:

Track experiments on fiber stresses in steel rails under weights of driving wheels.

Weight of rail.	Ballast.	Wheel load.	Fiber stress in base of rail, per square inch.
Pounds.		*Pounds.*	*Pounds.*
60	Stone	21,900	19,540
70	Gravel	21,900	18,620
85	...do	24,250	17,120
100	Stone	21,900	9,840
100	...do	21,900	[1] 18,970
95	Frozen gravel	18,750	11,450

[1] 1 tie removed.

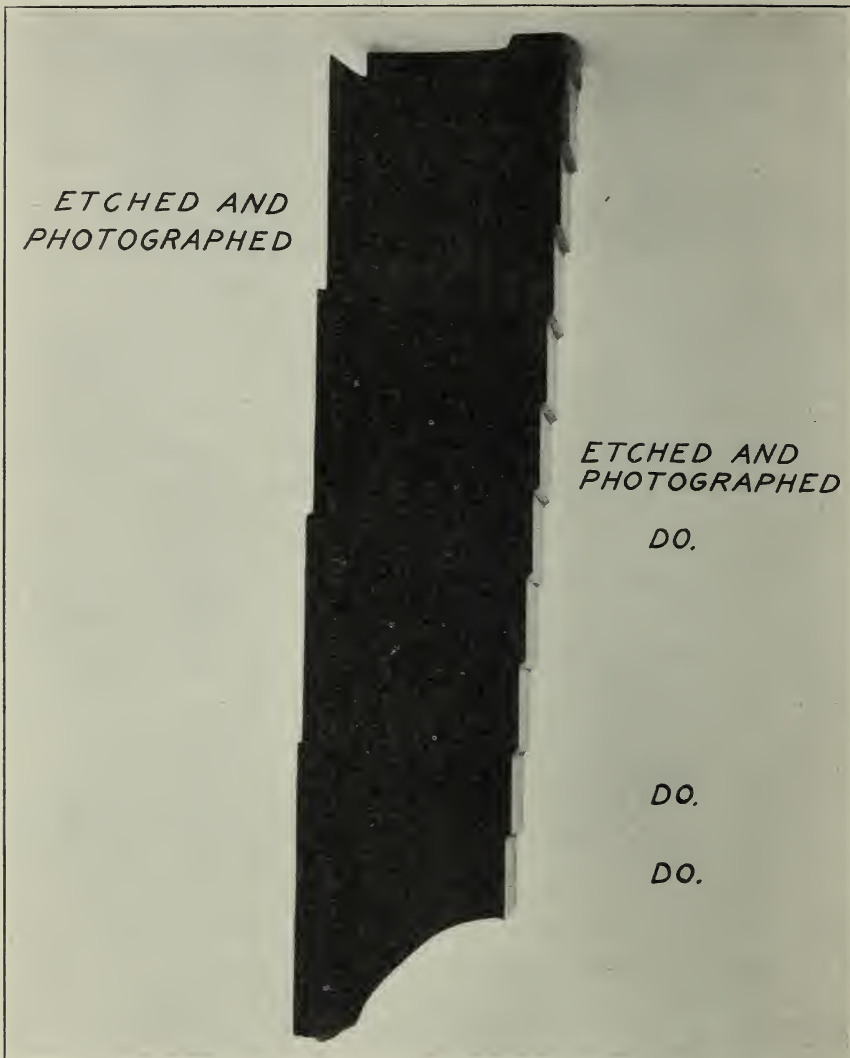
The above results were obtained under slowly moving engines and represent the maximum stresses observed.

The wheel loads were lower than found in present equipment, notwithstanding which the fiber stresses which they caused were high in comparison with allowable stresses in bridges and buildings, not to mention the alternate character of the stresses in the rails.

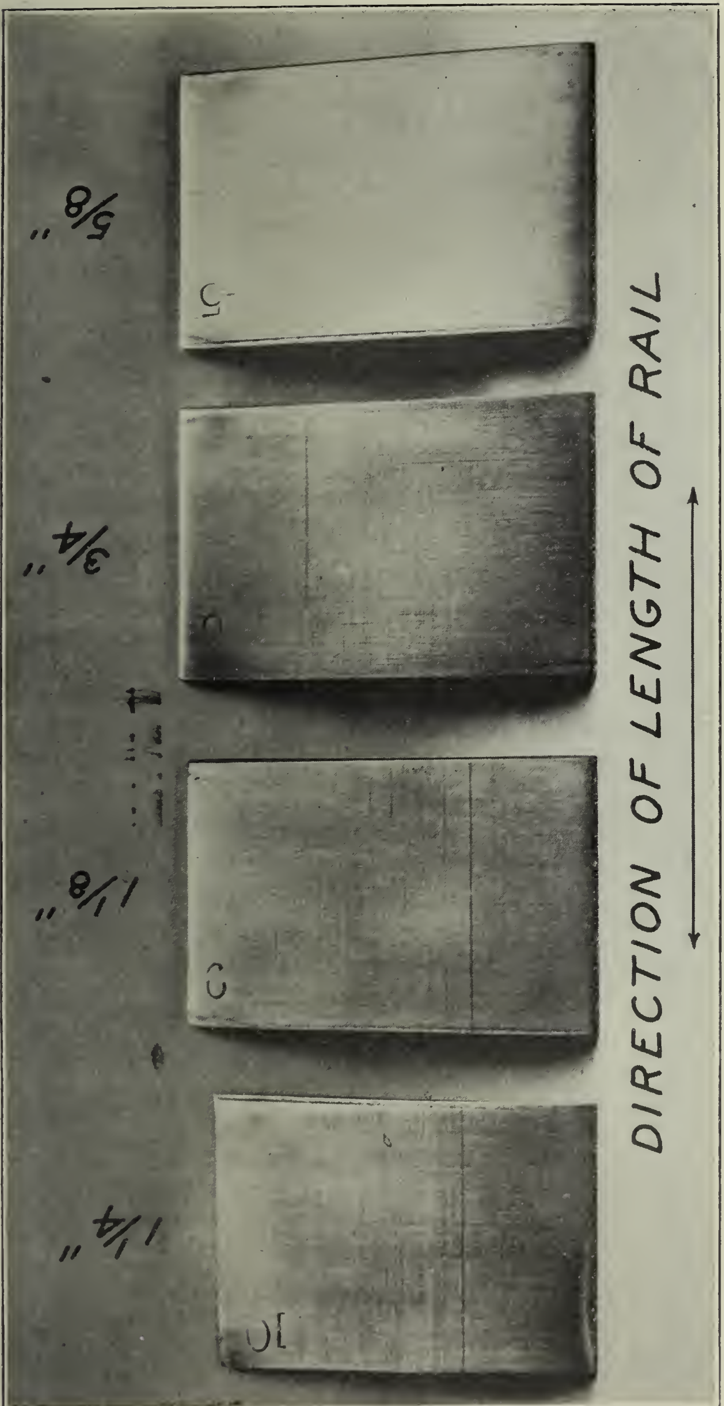
It may be remarked that current specifications governing the acceptance of steel rails, in common with other specifications, are directed toward securing certain properties in the finished material, which are rarely expected to be displayed in service, while no mention is made of limiting the fiber stresses in the track. This condition of affairs is in contrast with engineering practice in respect to bridges, viaducts, and steel frames of buildings where maximum unit stresses are prescribed.

Referring to the particular rail under consideration, the splitting of the head and the starting of longitudinal cracks in a number of places indicated a seamy state of the metal. The examination of the rail included this feature, although seaminess of the steel is not believed to have contributed toward causing the wreck of train No. 73.

Fragment No. 4 was planed off on the head and base with steps of one-eighth inch each, as shown by figure No. 8. At each of these steps the metal was found to be streaked, rather more pronounced at depths of one-fourth inch and more in the head than nearer the surface. Photographic print, figure No. 9, shows the appearance of four sections from the head, at depths below the running surface of five-eighths inch, three-fourths inch, $1\frac{1}{8}$ inches, and $1\frac{1}{4}$ inches, respectively, taken from right to left. The metal was smooth polished and etched with tincture of iodine. These sections, planed down to a thickness of one-sixteenth inch, were bent transversely, and frac-



No. 8. Fragment No. 4 planed down, head and base, in steps of ⅛ inch each, disclosing streaked metal at each surface.



No. 9. Strips from head of rail at steps 5/8 inch, 3/4 inch, 1 1/8 inches, and 1 1/4 inches below running surface, as shown by figure No. 8. Surfaces polished, and etched with tincture of iodine, showing streaks in steel.

tures were developed, following in general the dark lines which the etching brought into view. Figure No. 10 shows the streaked appearance of the metal of the base, as found at a depth of one-half inch from the lower surface of the base.

These streaks, which indicate lines of structural inequality, were plainly visible macroscopically and appeared more conspicuous on the etched specimens themselves than the photographic prints show. The slice taken from the head, $1\frac{1}{8}$ inches below the running surface, was photographed with a magnification of about 3.2 diameters. It was then bent and a line of rupture started along one of the principal dark lines. Figure No. 11 shows the appearance of this slice before and after it was partially fractured by a bending stress.

The streaked structure of the steel thus accounts for the several longitudinal cracks started in the rail at the time of the derailment. From the positions occupied and the distribution of the streaks throughout the cross section of the rail it would appear that a streaked, laminated structure prevailed generally throughout the metal. Such a condition is attributed to conditions starting with the ingot. Interior streaks of this kind are not to be confounded with shrinkage cracks or surface defects incident to rolling the rails.

The dark areas shown on the photographic prints, figure No. 12, represent shrinkage cracks extending inward from the surface of the ingot. These oxidized areas would necessarily be located at or near the surface in the finished rail, and cause defects of quite another order from those witnessed in the interior metal of the present rail.

In conclusion it appears:

That the derailment and wreck of train No. 73 was caused by the rupture of the rail herein described.

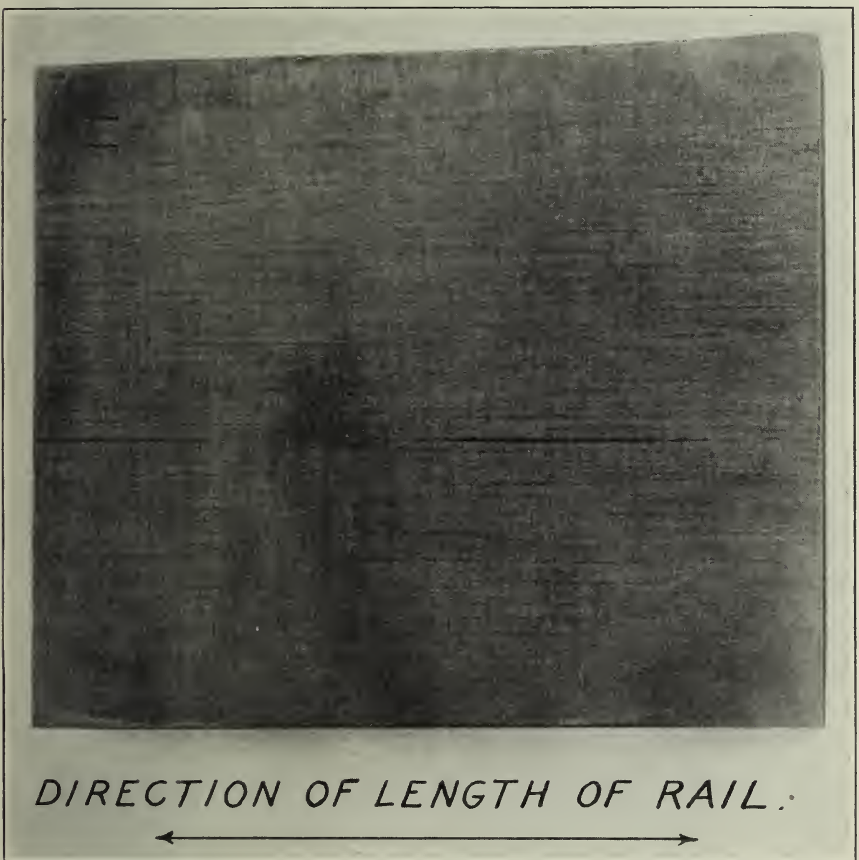
That the rail displayed a transverse fissure in the head, on the gauge side, about 1 inch in diameter.

That the initial rupture of the rail was at the fracture containing this transverse fissure, or at an adjacent fracture, the battered condition of which precluded passing judgment upon the bearing which it had in the derailment.

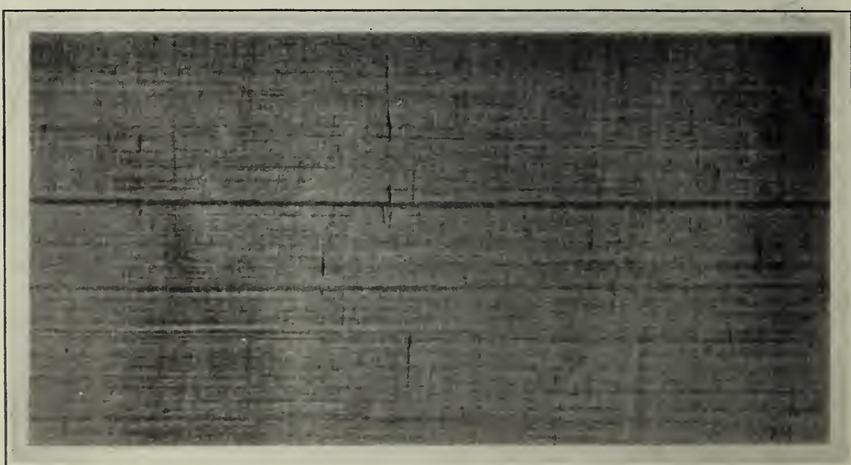
That the initial rupture of the rail was probably caused by the eastbound train, which passed over the track next before the westbound (wrecked) train.

That the track was in good condition, excepting in the matter of the broken rail, and allowed the cars of the eastbound train to pass in safety over the fractured rail, assuming that the engine of the eastbound train caused the rupture.

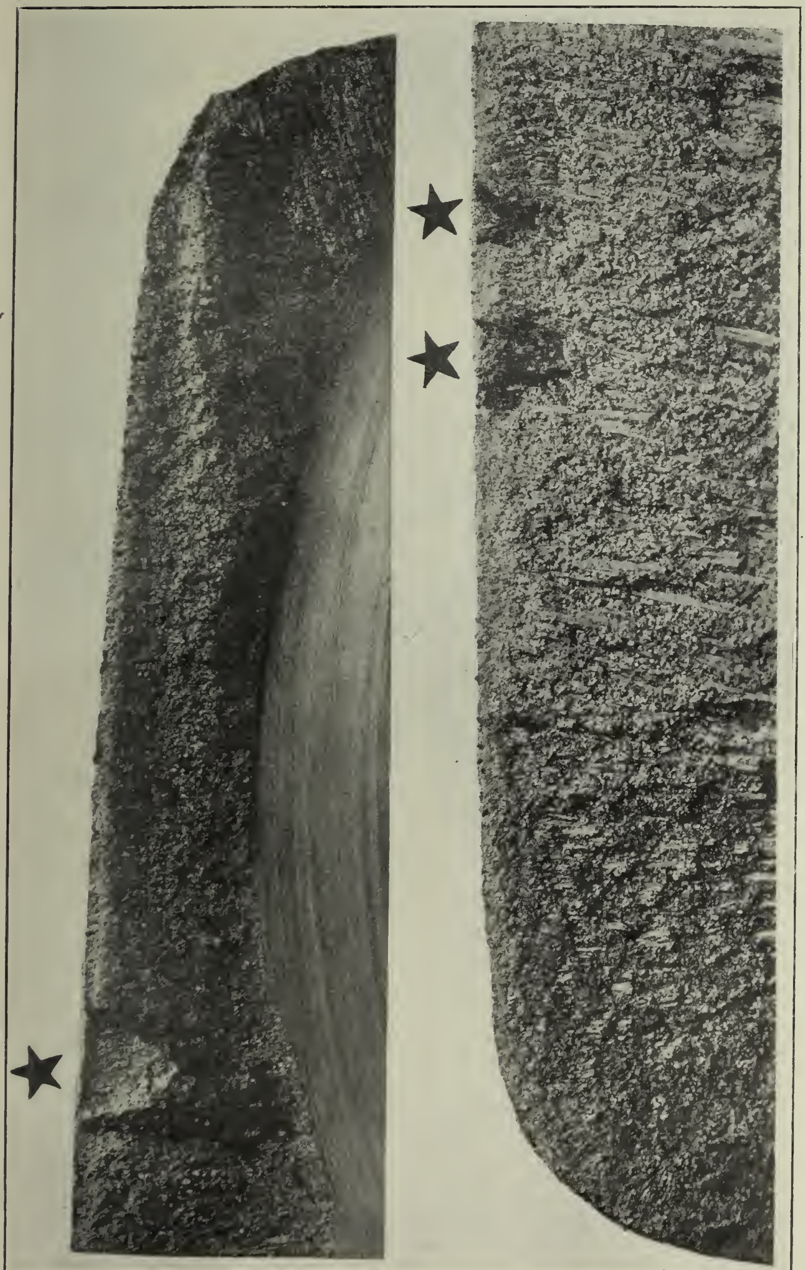
That the westbound (wrecked) train caused additional lines of rupture, and left the track through the opening made by the several fragments of the rail.



No. 10. Strips from base of rail at depth of ½ inch from lower surface, as shown by figure No. 8. Surface polished, and etched with tincture of iodine, showing streaks in steel.



No. 11. Strip from head of rail at depth of $1\frac{1}{8}$ inches below running surface of head, polished, and etched with tincture of iodine, showing streaks in steel; magnified about 3.2 diameters. Upper figure before bending; lower figure showing line of fracture made by bending, which followed dark streak in steel.



No. 12. Fractured surfaces of rail-steel ingot, showing shrinkage cracks, indicated by stars.

That the metal of the rail was low in ductility and brittle as shown by the tensile test pieces, but it will not be inferred from that fact alone that the rail would not endure successfully repeated stresses up to a certain maximum.

That the actual fiber stresses of service in the case of this rail, and that of rails in general are not known, whereas there is urgent need for such information.

That the margin in strength or factor of safety existing, or which should exist, in railway track does not admit of being known while the stresses to which the rails are subjected are unknown. Such information does not constitute all that is required in judging of safe or unsafe conditions in railway practice, but would furnish valuable aid toward that end.

That knowledge of overstraining of rails should be obtained by direct measurement in the track.

That the prevalence of rail failures, for which transverse fissures are accountable, is such as to demand inquiry into the conditions which are present and contributory in the formation of such failures, that means may be adopted looking toward their elimination.

Respectfully submitted.

James E. Howard,
Engineer-Physicist.

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